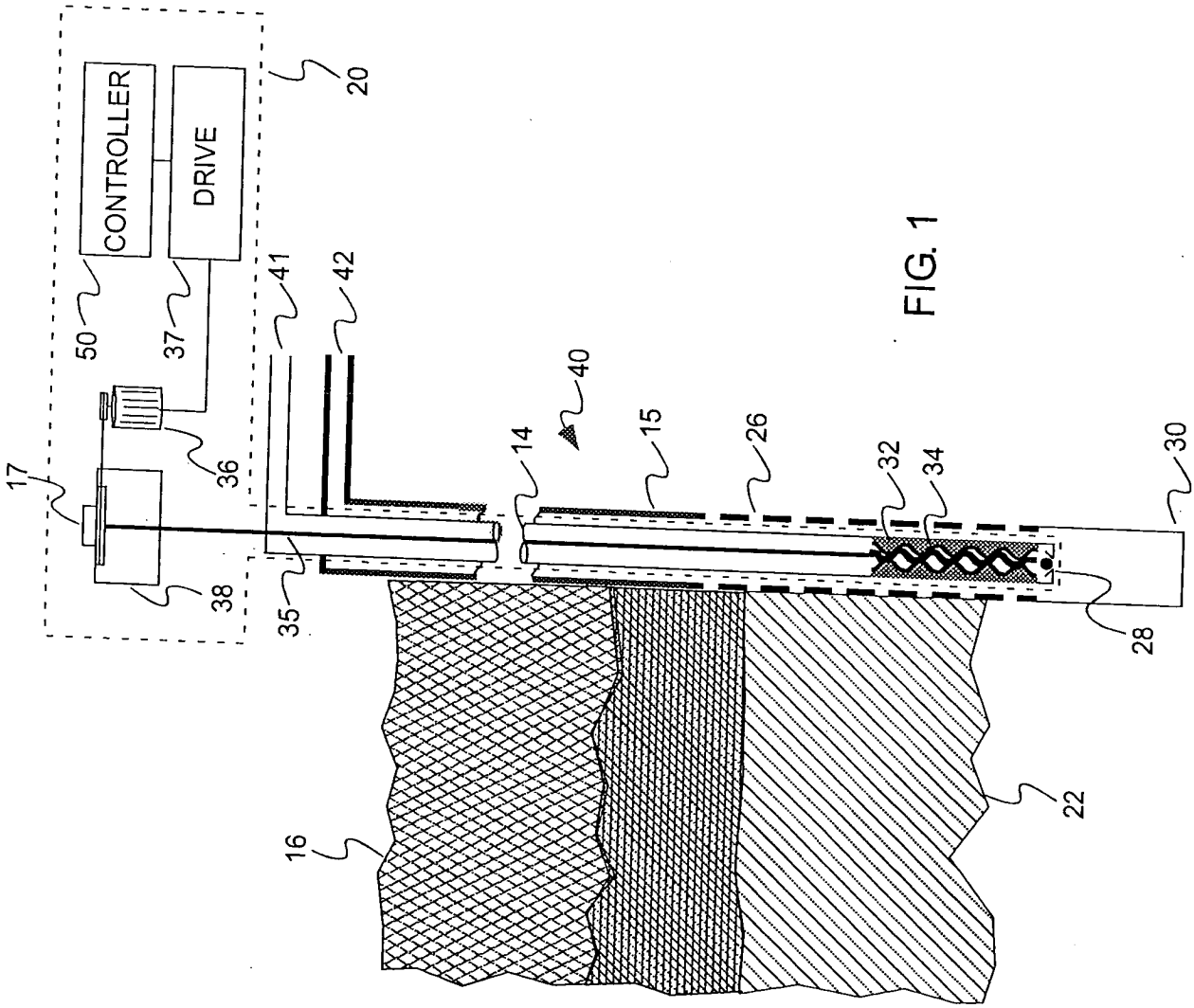

CONTROLLER
DRIVE
20
50
37
41
42
40
14
15
26
32
34
30
17
36
38
35
28
22
16

FIG. 1

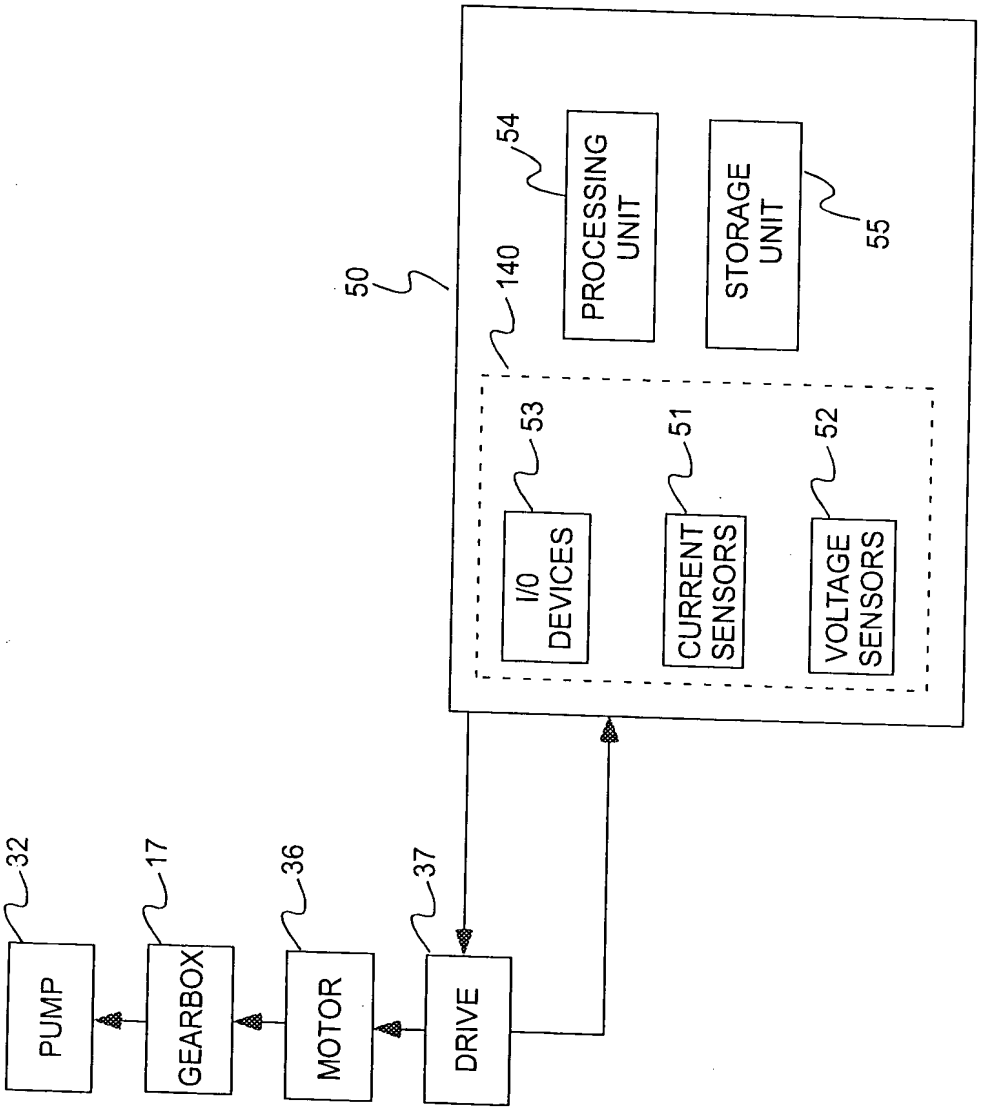
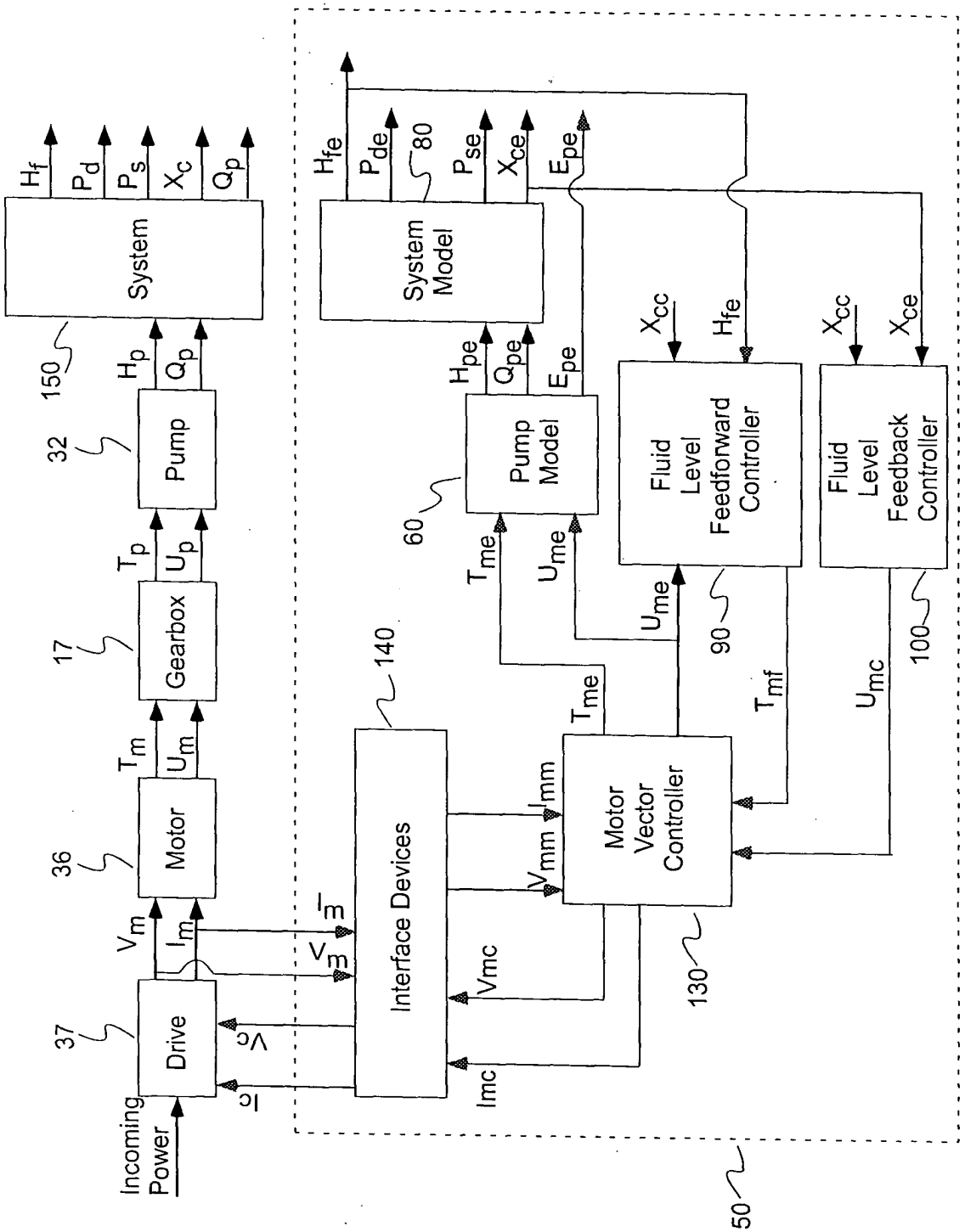
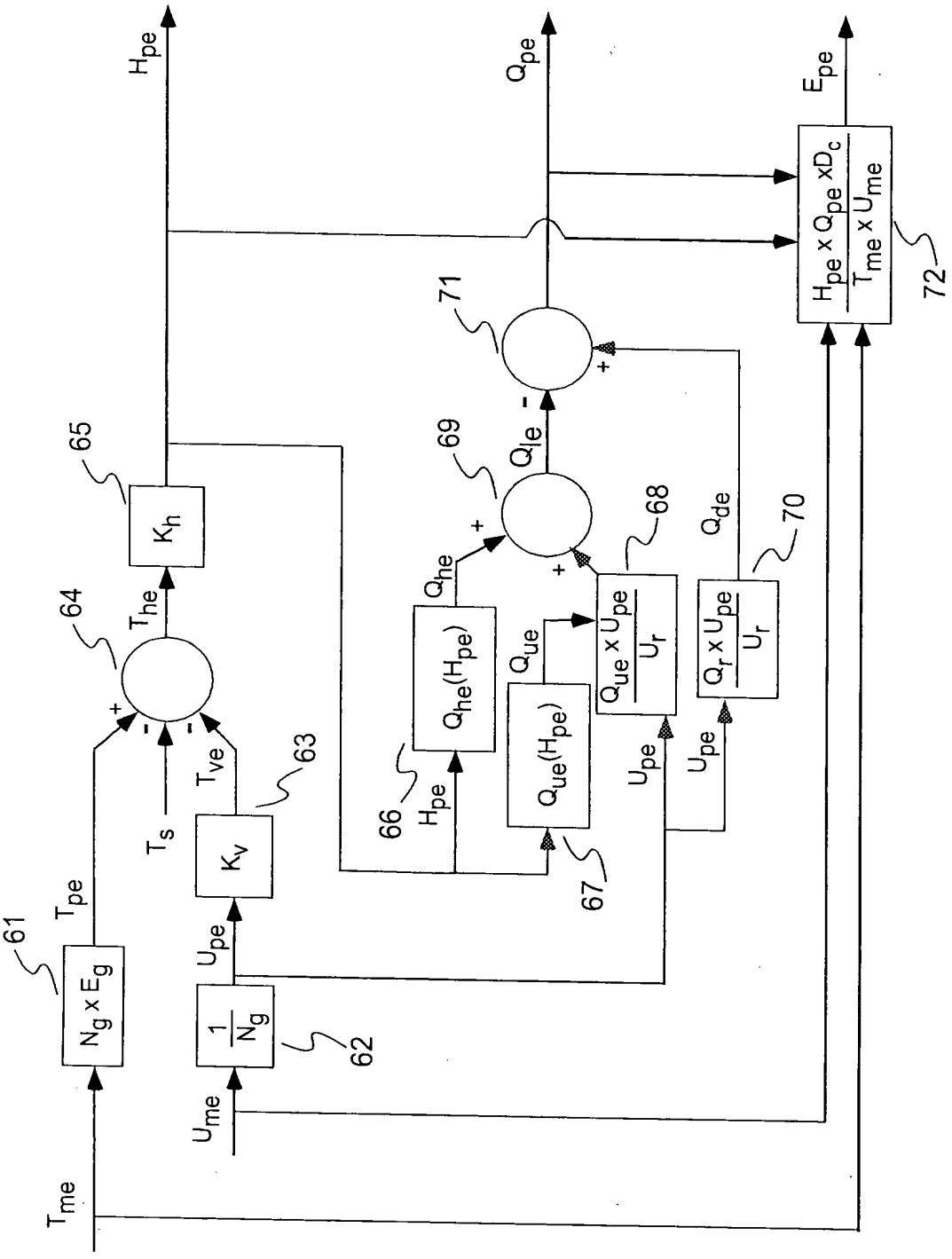

50
140
54
PROCESSING UNIT
STORAGE UNIT
55
I/O DEVICES
53
CURRENT SENSORS
51
VOLTAGE SENSORS
52
PUMP
32
GEARBOX
17
MOTOR
36
DRIVE
37
20

FIG. 2

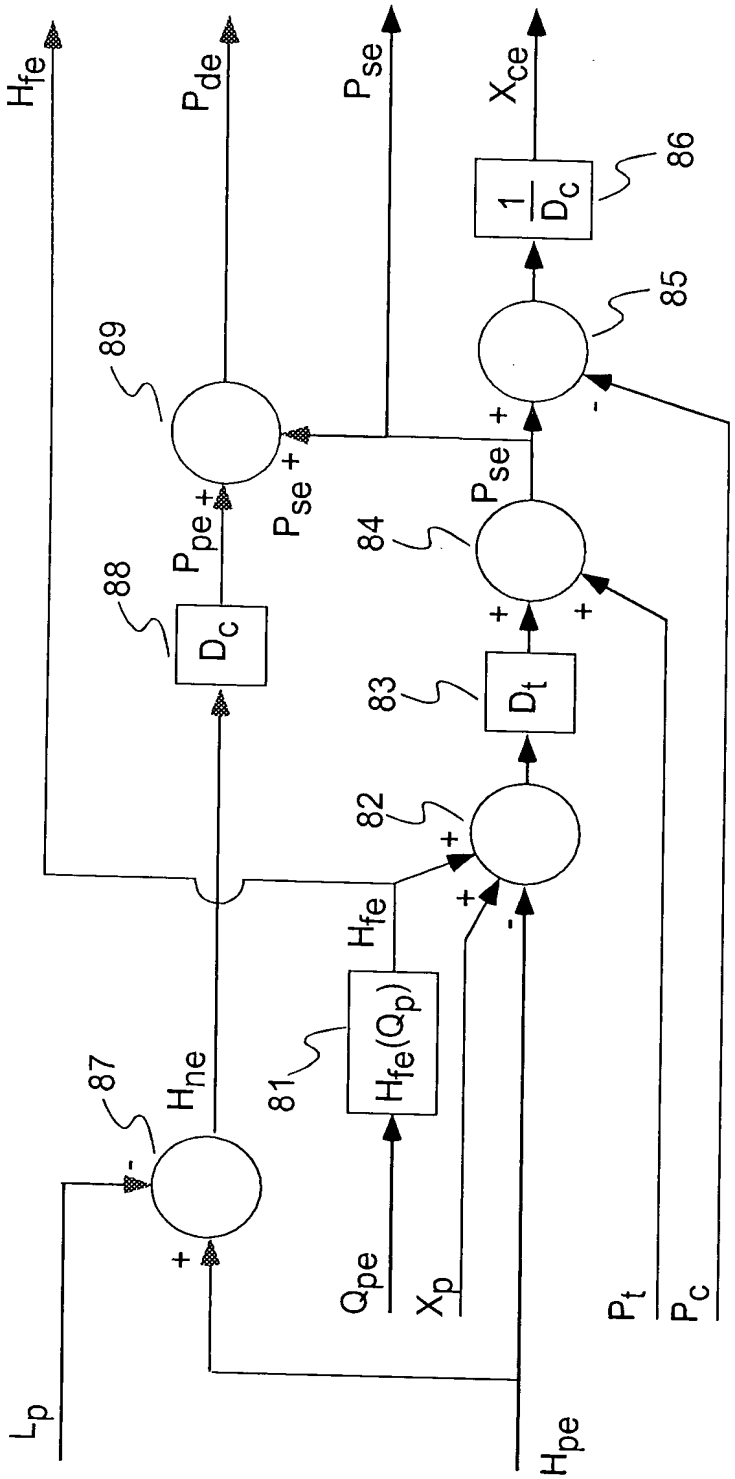

Incoming Power
Drive
37
Motor
36
Gearbox
17
Pump
32
System
150
Interface Devices
140
System Model
80
Pump Model
60
Fluid Level Feedforward Controller
90
Fluid Level Feedback Controller
100
Motor Vector Controller
130
50
H_f
P_d
P_s
X_c
Q_p
H_p
Q_p
T_p
U_p
T_m
U_m
V_m
I_m
V_c
I_c
$\overline{I_m}$
$\overline{V_m}$
H_{fe}
P_{de}
P_{se}
X_{ce}
E_{pe}
H_{pe}
Q_{pe}
E_{pe}
T_{me}
U_{me}
X_{cc}
H_{fe}
U_{me}
T_{me}
T_{mf}
X_{cc}
X_{ce}
U_{mc}
I_{mm}
V_{mm}
V_{mc}
I_{mc}

20

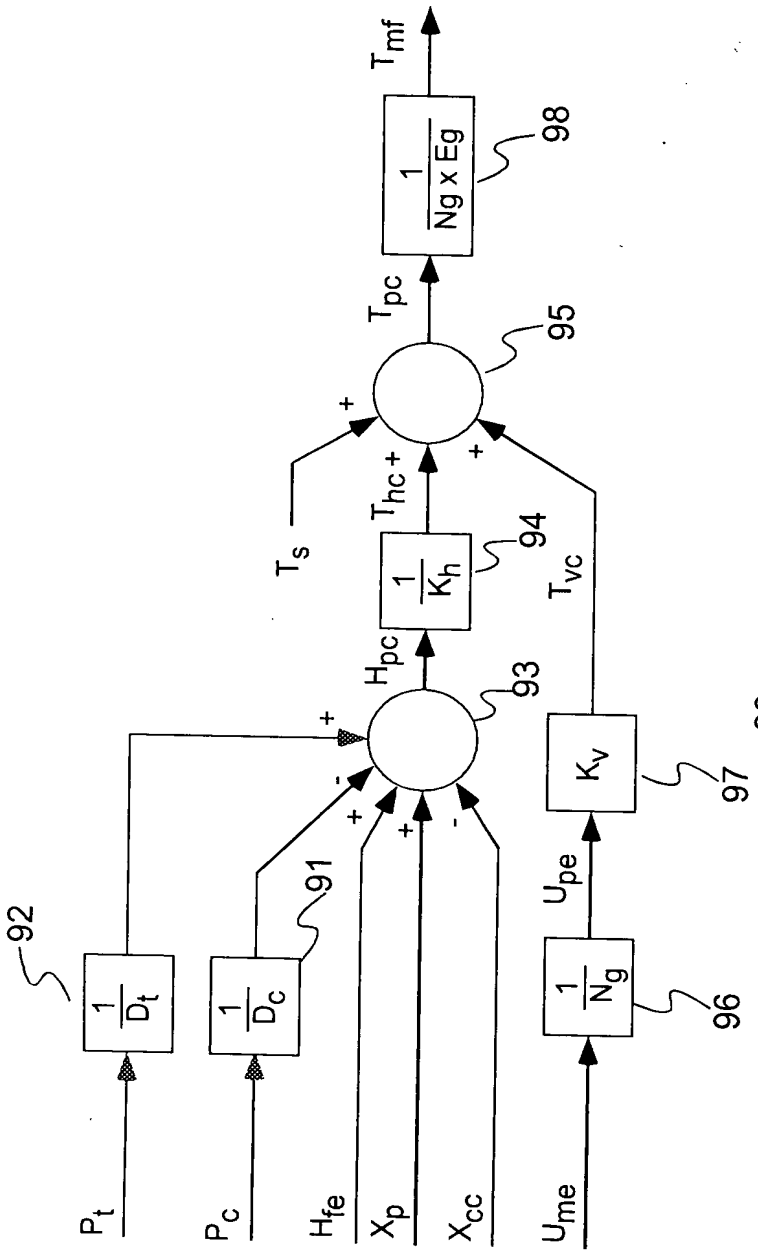
FIG. 3


H_{pe}
Q_{pe}
E_{pe}
$\frac{H_{pe} \times Q_{pe} \times D_c}{T_{me} \times U_{me}}$
72
71
69
Q_{le}
65
K_h
64
T_{he}
Q_{he}
Q_{de}
70
68
$\frac{Q_{ue} \times U_{pe}}{U_r}$
$\frac{Q_r \times U_{pe}}{U_r}$
$Q_{he}(H_{pe})$
Q_{ue}
$Q_{ue}(H_{pe})$
66
67
H_{pe}
U_{pe}
T_s
T_{ve}
63
K_v
T_{pe}
61
$N_g \times E_g$
$\frac{1}{N_g}$
62
U_{me}
T_{me}

60
FIG. 4

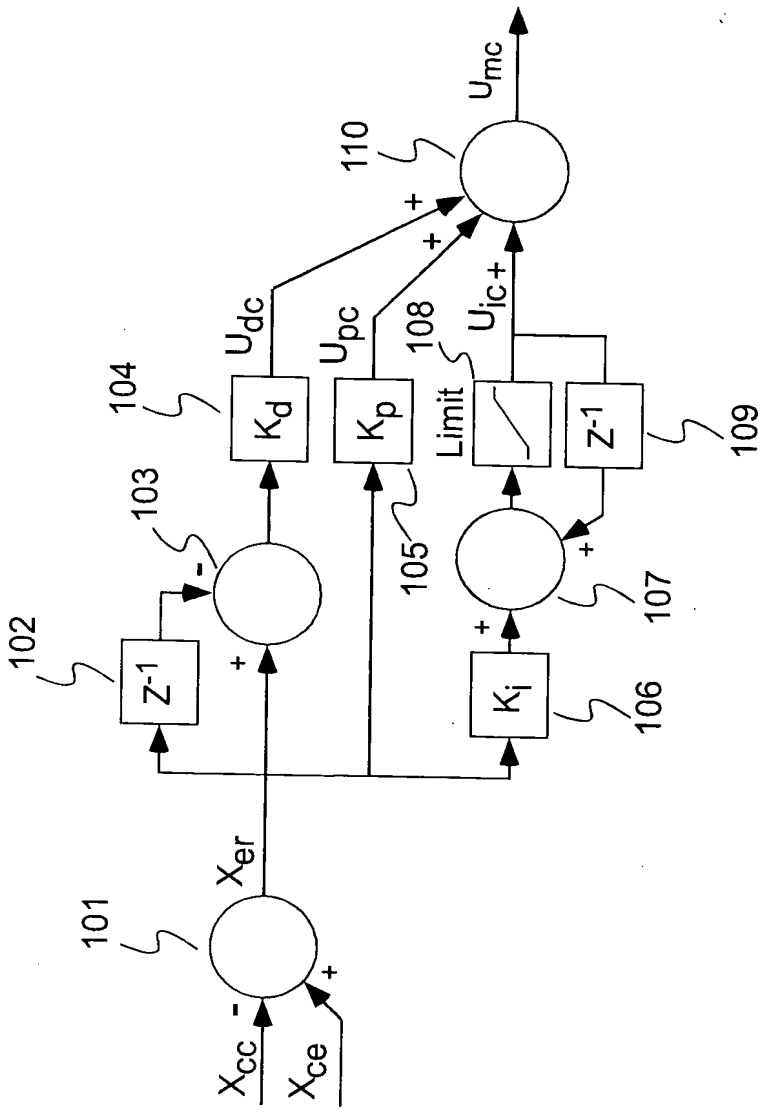

Hfe
Pde
Pse
Xce
86
1/Dc
85
89
Pse +
Pse +
84
88
Ppe +
Dc
83
Dt
82
Hfe
Hfe(Qp)
81
87
Hne
Lp
Qpe
Xp
Pt
Pc
Hpe

80
FIG. 5


T_{mf}
$\frac{1}{Ng \times Eg}$
98
T_{pc}
95
+
+
T_s
T_{hc} +
$\frac{1}{K_h}$
94
T_{vc}
H_{pc}
93
+
-
+
+
-
K_v
97
92
$\frac{1}{D_t}$
$\frac{1}{D_c}$
91
U_{pe}
$\frac{1}{N_g}$
96
P_t
P_c
H_{fe}
X_p
X_{cc}
U_{me}

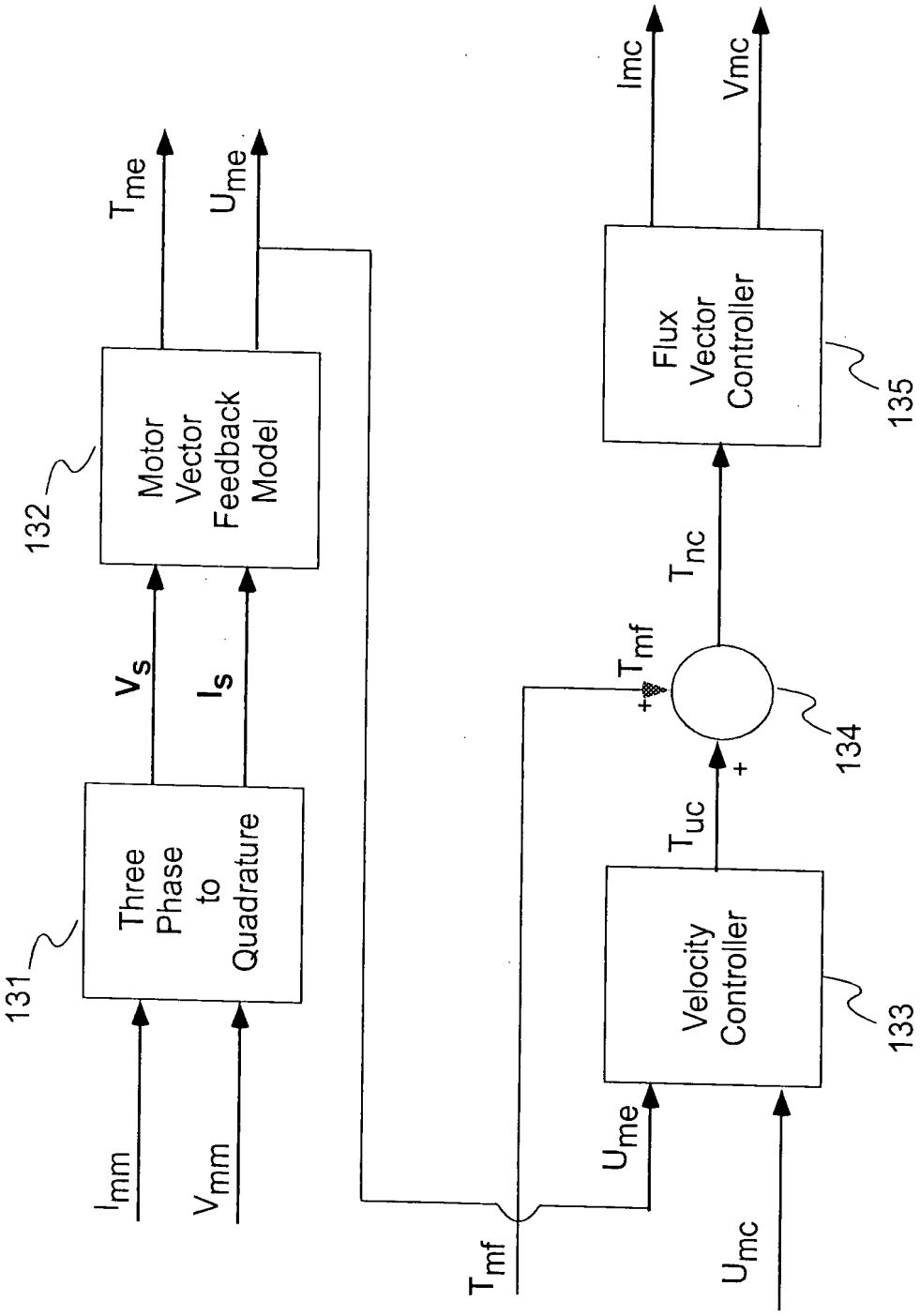
90

FIG. 6


U_{mc}
110
+
+
U_{dc}
U_{pc}
108
U_{ic}+
104
K_d
K_p
Limit
Z^{-1}
109
103
-
105
+
107
102
Z^{-1}
+
+
K_i
106
X_{er}
101
-
+
X_{cc}
X_{ce}

100

FIG. 7


Three Phase to Quadrature
131
Motor Vector Feedback Model
132
Flux Vector Controller
135
Velocity Controller
133
134
I_{mm}
V_{mm}
V_s
I_s
T_{me}
U_{me}
I_{mc}
V_{mc}
T_{nc}
T_{mf}
T_{uc}
U_{me}
U_{mc}
T_{mf}
+
+

130
FIG. 8

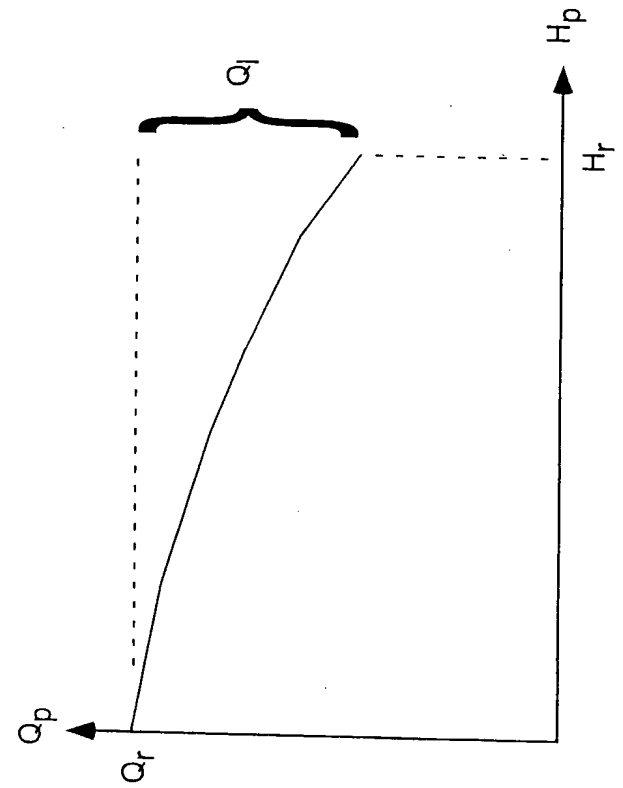

Typical PCP Curves
at Rated Speed U_r
H_p
Q_l
H_r
Q_p
Q_r

FIG. 10

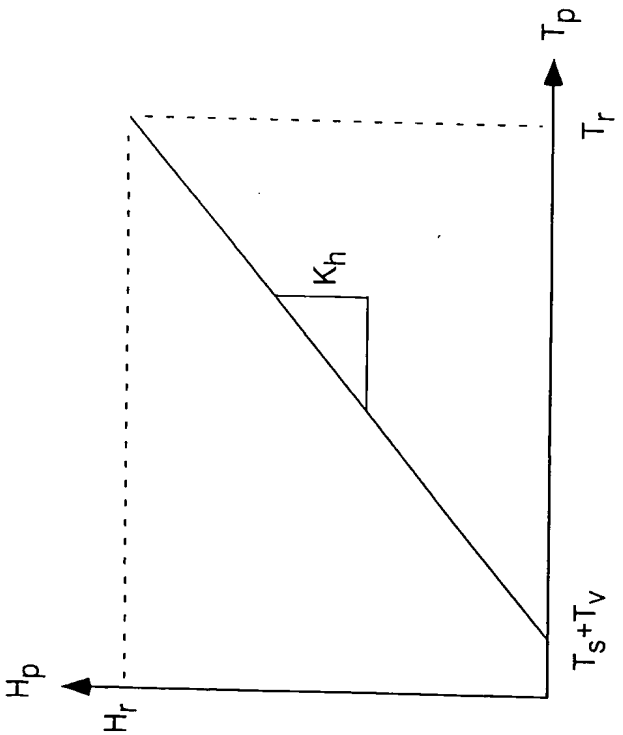
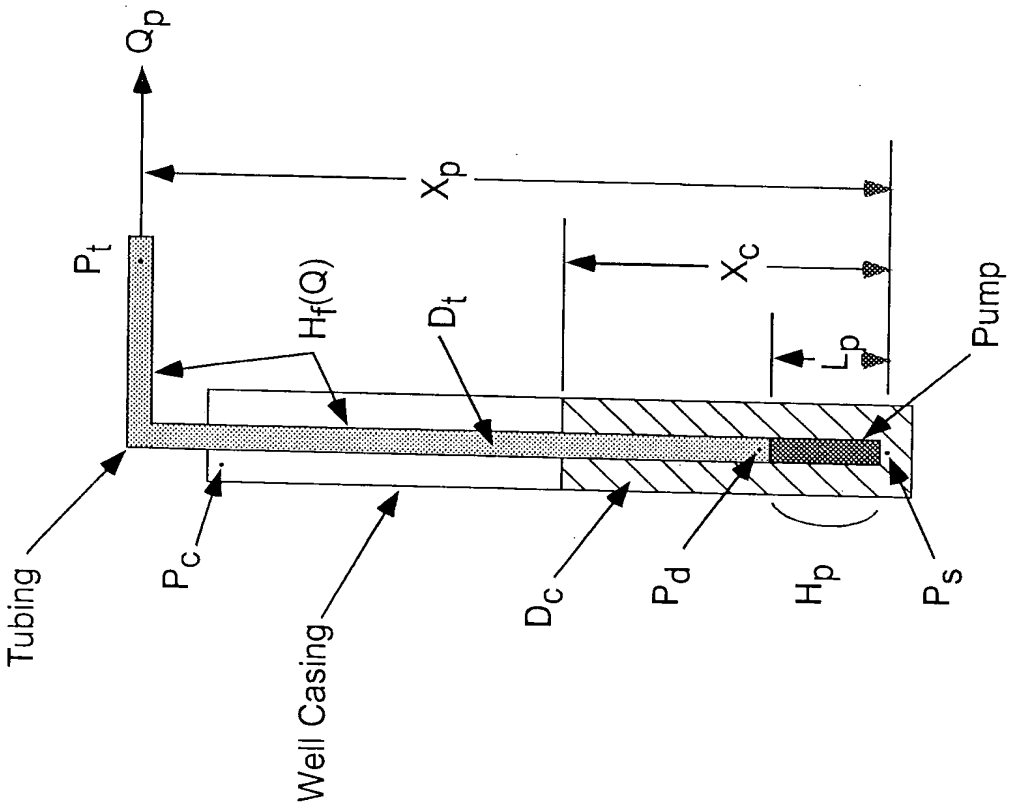

T_p
T_r
K_h
H_p
H_r
T_s+T_v

FIG. 9



150
FIG. 11

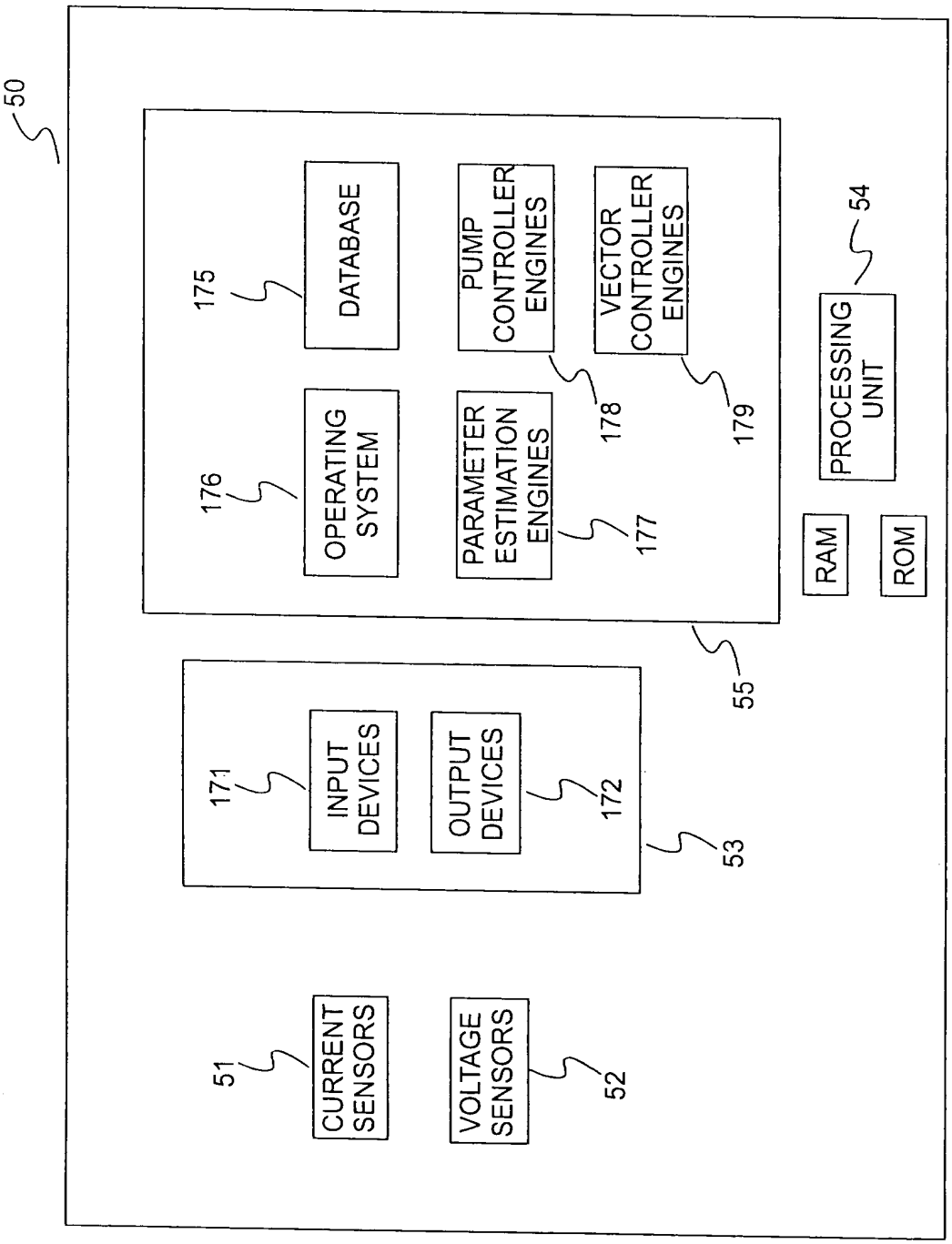

50
175
DATABASE
176
OPERATING SYSTEM
PUMP CONTROLLER ENGINES
178
PARAMETER ESTIMATION ENGINES
177
VECTOR CONTROLLER ENGINES
179
55
RAM
ROM
PROCESSING UNIT
54
171
INPUT DEVICES
OUTPUT DEVICES
172
53
51
CURRENT SENSORS
VOLTAGE SENSORS
52

FIG. 12

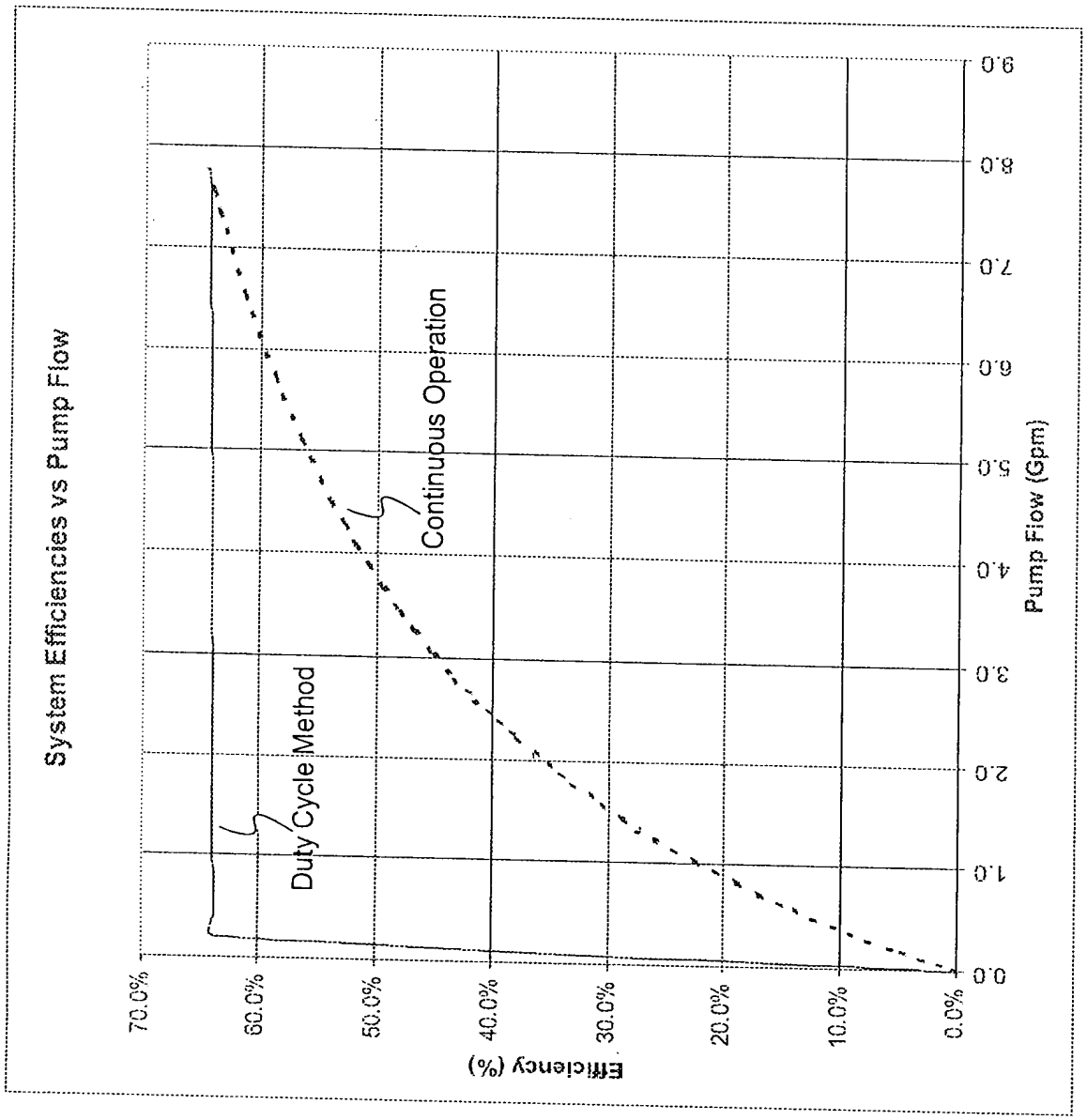

System Efficiencies vs Pump Flow
Duty Cycle Method
Continuous Operation
Efficiency (%)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Pump Flow (Gpm)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

FIG. 13